§11. Fracture Toughness of SUS316 and TIG Weldment in High Magnetic Field under Cryogenic Temperature

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An austenitic stainless steel (SUS316) is used for cryogenic structures, which are a support structure for an electro-magnetic force and helical coil cans, in Large Helical Device. Thickness of these plates becomes up to around 100 mm for supporting a large electro-magnetic force and these materials must be weldable under the assembly. Since an assembly accuracy must be kept on well, a heat input during welding should be reduced, and a partial welding is usually applicable. As the unwelded portion, which is sometimes like a natural crack, will remain in the center part of the plate thickness after the partial welding, a fracture toughness at the tip of the unwelded portion must be evaluated experimentally in a high magnetic field under a cryogenic temperature.

In this study, to evaluate the real fracture toughness of the natural crack, the partial welded joint was prepared and the fracture toughness test was performed in a high magnetic field under 4.2K based on ASTM E813-89.

A butt weld groove shape of the partial welding joint is shown in Fig.1. In this figure, a location of a compact tension specimen (CT specimen) is also described. The first pass of welding was carried out by a tungsten inert gas arc welding (TIG welding), and the following passes were done by a metal arc gas welding (MAG welding). The total numbers of passes were 20 passes. During the welding, both plates were compressed to each other to achieve a metal touch on the unwelded portion. From an observation result of a weld root, a real crack of around 80 μm existed at a crack tip. After welding, CT specimens were machined out without a post-weld heat treatment. The configuration and dimension of this CT specimen are the same as Jin Chan's specimen.[1] Specimen thickness is 12.7 mm. Side grooves and a fatigue pre-crack were not induced in this welded specimen and a ductile crack propagated from the natural crack in a thickness direction of the base plate during the fracture toughness tesing.

Base metal specimens were also prepared to compare with the welded specimens. These base metal specimens were machined out from a mid-section of the same base plate and a fatigue pre-crack was induced at the tip of machined notch.

The fracture toughness tests were carried out under 0T, 8T and 14T in a liquid helium by using a bitter magnet. A special mechanical testing machine was manufactured and inserted to the bitter magnet. During the fracture toughness testing, a stroke speed was controlled at 5×10^{-3} mm/sec and a single-specimen technique was applied for evaluation of the fracture toughness.

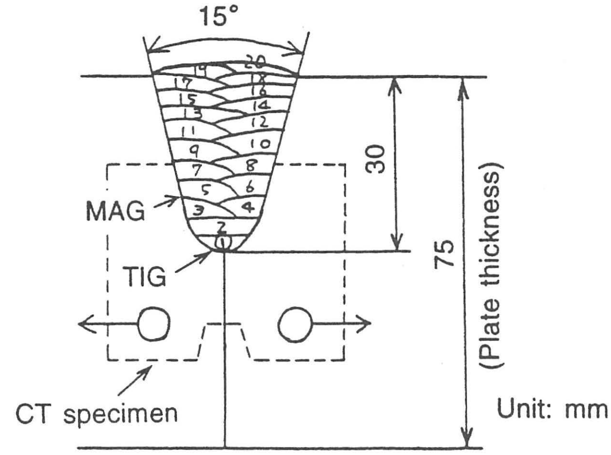

Fig.1 Weld groove shape and specimen location

After the evaluation of the fracture toughness, it is clarified that SUS 316 base metal has the toughness of over 340 MPa√m and the natural crack in the welded joint shows over 140 MPa√m. Moreover, the magnetic field effect on the fracture toughness is not so much and the toughness is increased gradually in the high magnetic field. This tendency does not agree well with other data.[2]

This study was performed under the collaboration of Lawrence Berkeley Laboratory, National Institute of standards and Technology, Francis Bitter National Magnet Laboratory in USA and Hitachi Ltd.

Reference
1) Chan, J.W., Glazer, J., Mei, Z. and Morris,Jr., J.W., Adv. Cryog. Eng. Mat. 36 (1990) 1299
2) Shibata, K., Cryog. Eng. 26-4 (1991) 251